General classification scheme for outdoor sound propagation situations

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Introduction

Noise assessment normally considers a long term average energy equivalent sound pressure level (Leq) and a maximum level (Lmax) to indicate the noise situation for correlation with noise impairment, e. g. annoyance. Acoustical time and frequency weightings applied to these levels are said to take into account the sensitivity of human hearing. In addition, level adjustments are added to correct the levels for particular sound specific reception impairment potential and to make the rating levels comparable to single numbered noise limits. This concept is found throughout many national and local regulations.

Furthermore, the prediction or measurement of these two indicators is often meant to focus on the so-called downwind or better to say favorable sound propagation situation in order to find the highest value for this comparison. As a consequence, most ‘noise’ propagation schemes in the noise specific guidelines for traffic noise, railroad noise, industrial noise and so on just hold for this very condition, for particular acoustical time and frequency weighting and take into account only those the physical phenomena that play a role within the constraints of the model purpose.

It is clear, that the information on noise situations from these two indicators is rather poor and really not sufficient to make reliable assessments. However, in the beginning of noise assessment it was impossible to do better due to the poor understanding of the propagation of sound outdoors and due to the low numerical power that was available. There are several reasons to go beyond and to overcome the constraints of a two-level-indicator concept. Based on the improved knowledge about the sound propagation outdoors and using the increasing computer power and the facilities of modern measurement systems, it is possible to make progress in the field of environmental noise control.

One step beyond the two-level-indicator concept means for example to predict a level distribution to indicate a certain noise situation. This distribution will add options to study noise situations with respect to annoyance. Another step beyond is to make prediction for a given propagation condition, i.e. different weather and ground conditions. Both steps are a challenge under several aspects. This paper focuses on a proposal on how to define model independent weather and ground condition and how to achieve a distribution in a standardized way.

Class figures	1		2		3		4		5		6		7	
Source size	**small**		**medium**		**large**		**very large**		**super large**					
Weber radius [m]	1	2	2	4	4	6	6	10	10	30				
frequency [Hz]	200	100	100	63	63	50	50	40	40	31				
Source height	**low**		**medium**		**high**		**very high**		**sky high**					
height [m]	0	1	1	3	3	6	6	10	10	100				
Distance	**close up**		**first nbh.[1]**		**close nbh.[1]**		**medium nbh.[1]**		**far nbh[1].**		**large distance**		**out of range**	
distance [m]	495	505	990 to	1010	1980	2020	2970	3030	5940	6060	9900	10100	24750	25250
Receiver height	**low**		**medium**		**high**		**highest**		**sky high**					
height [m]	0	1	1	3	3	6	6	10	10	30				
G-atten.[2] source	**very low**		**low**		**medium**		**high**		**very high**					
energy loss [%]	0	10	10	30	30	60	60	80	80	100				
G-atten.[2] propagation	**very low**		**low**		**medium**		**high**		**very high**					
energy loss [%]	0	10	10	30	30	60	60	80	80	100				
G-atten.[2] receiver	**very low**		**low**		**medium**		**high**		**very high**					
energy loss [%]	0	10	10	30	30	60	60	80	80	100				
Air attenuation	**very low**		**low**		**medium**		**high**		**very high**					
loss at 1kHz [dB/km]	0	1	1	2	2	3	3	5	5	10				
Refraction	**upwind**						**no wind**		**downwind**					
	strong		**moderate**		**weak**		**neutral**		**weak**		**moderate**		**strong**	
radius of curvature [m]	-500	-2000	-2000	-5000	-5000	-8000	-8000	8000	8000	5000	5000	2000	2000	500

Table 1 Classification of sound propagation situations.
General categories bold, followed by metered scales of observable measure(s), [1]neighbourhood, [2]ground attenuation

Propagation models

Today, many sound propagation models are available. They differ with respect to purpose and physical background and preconditions. There are simple models allowing very fast codes to make predictions for modern noise management schemes that allowing loud operations under unfavorable propagation conditions and restricting these operations under favorable conditions. There are sophisticated models to study the interaction between wind and walls for example in order to design noise abatement measures. There are engineering models handling a multitude of sources and calculating noise maps to deduce guidelines for noise policy and general strategies.

Predicting a level distribution does not mean that new models are needed. Most of the available models can predict a distribution because they can consider different weather and ground situations. However, many phenomena of the sound propagation outdoors play an important role dependent on purpose; and the models take care of them in a different way needing different indicators of the source, of wind and weather and of the ground features for example. Hence, the relevant input parameters are in many cases part of the model itself. In order to generate a model independent scheme, weather, ground and also the geometry must be defined in general terms. The paper proposes to define so-called categories of sound propagation. These categories do not refer to physical phenomena but rely on overall observations to describe the sound propagation.

For example, there is the category 'air attenuation'. Air absorption, the contribution of turbulence and losses due to the presence of vegetation go into the air attenuation category.

Table 1 shows the principle scheme of a general classification for sound propagation situations. There are 9 categories: the source, the source height, the receiver height, the air absorption, three categories for ground attenuation (close to the source, close to the receiver and along the propagation path) and the refraction. Each category is divided into a reasonable number of classes which covers all states in the category without missing bins. These classes are simply denoted by a name. A combination of one selected class for each category makes up a propagation situation class.

At first sight, this general classification is not very helpful because model designers would not find any input parameter useful for their models. If applied however to a noise environment, it is possible to add metered observation measures to each class that describes the meaning of the class for that noise and for the prediction purpose.

Table 1 provides such metered classification beneath the general classes of the categories for high energy blast noise. There are for instance two metered rows to describe the source. There are ranges for the so-called Weber-radius of a blast and also and independently for the centre frequency of the blast. There is a metered scale of the radius of curvature to describe the refraction. These scales do not mean that a model must use these measures as input parameter, but they give the model designer an idea what is meant with the class. If a model, for instance, cannot take a Weber-Radius to describe the blast source spectrum, it may use a frequency range to describe the frequency dependent features of the model. Metered observations are meant as a guideline to determine an appropriate setting for model-specific input parameters.

It is clear that a different kind of noise will need a different meaning for the general classes. There will be different metered observations for example for the height of the source and the distance for rail road noise and wind turbine noise.

Metered observation must be a single number 'scalable' to a range, in order to clearly define the start up condition for any propagation model. Good examples for such measures describing the weather are the wind strength (ground wind at 10 m height) in terms of Beaufort classes, the temperature measured at a certain height above ground, the cloud cover given in eighths or fourths re. overcast and the amount of rainfall per day or snow cover. All weather observations must be valid for a situation (for a certain volume of the atmosphere during a certain time period) that is assumed to be representative for the propagation. A bad example in this context would be the wind speed profile, because these profiles are not scalable without an additional restraining atmospheric model. This atmospheric model should be part of the propagation model.

Applying the classification scheme to a particular model is therefore a task that is model-specific. Elementary models will probably degenerate the metered observations into their small set of input parameters. Sophisticated models may ask for even more information than provided by the metered observations and must make additional assumptions. Therefore, this task can be a great challenge for some models. If the model cannot take a radius of curvature but it can take a sound speed profile, it is the task of the user to calculate the prediction for all sound speed profiles that the model would mean for instance for the "moderate downwind condition".

The distance classification may look strange because models rely on "exact" given values if applied to a particular situation. In practice however, the distances have uncertainties. It is necessary to give these uncertainties to built-up a range for the classification of this category. Also source and receiver heights are normally direct input parameters of the models. They are put into classes because in outdoor propagation acoustics it is not very helpful to calculate for one specified height only. Prediction should be representative for a source or receiver in a range above.

The result of the prediction for a given propagation class is not or not only a decibel number; it is a distribution of levels that the model produces due to the given range for each class of the here 9 categories: each distinct setting for the model input parameters yields a valid result for the propagation class and adds a new level to the distribution. Compiling the results into a distribution and given by percentiles – the 1, 5, 10, 20 … 80, 90, 95, 99 percentile as proposed here – will complete the step beyond the two-level-indicator concept.

Discussion

The application of the proposed classification has a lot of advantages. The output level distribution allows to estimate the range of levels that are to be expected for a given propagation situation. Different models may predict a similar average level, but they may predict a different spreading within a class. Therefore, the difference between the 10^{th} and 90^{th} percentile, as a reasonable measure for the span, adds an important criterion to validate the models versus measuring results. For instance, it is well-known that for moderate downwind propagation this span should be rather narrow compared to a moderate upwind distribution. Comparing the distribution for a situation with high ground attenuation to a distribution with low attenuation will give an idea, how levels changed after rain fall. In general, comparing the prediction of one model for different propagation situations shows the sensitivity of the model to the influence under consideration.

Table 1 provides 5 categories that focus on the weather and the ground condition, in total 5 x 5 x 5 x 5 x 7 = 4375 different propagation situations. For any noise prediction purpose, this total number is rather too high than too low. However, not all propagation classes will realize with the same probability. But it is necessary that every observed condition can be assigned to a class. The scheme allows to decrease the number of classes. If the reduced scheme only provides 2 classes in each category upwind or downwind, high air attenuation, low air attenuation and so on, there are still 32 principle classes to describe weather and ground.

Outlook

This propagation situation classification concept is proposed to the NALS Working group on sound propagation outdoors, primarily as general method to achieve distributions and as a standardized tool to compare model outputs. This working group drafts the new VDI guideline 4101 which will formulate source independent propagation schemes for arbitrary applications.